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## STUDIES IN THE BIOLOGY OF THE LEECH IX<sup>1</sup> THE GROSS NERVOUS SYSTEM

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### INTRODUCTION

To the student of animal behavior a knowledge of the nervous system of the organism under observation is of utmost importance. Experimental evidence has provided valuable data regarding the arrangement of the functional components of the action system of this organism but in a comprehensive analysis of behavior this source of information is inadequate. A review of the work of earlier investigators is informative and applicable in so far as they have revealed the anatomical organization of the nervous system of annelids in general. The work of Whitman, Bristol, and others is especially pertinent at this point inasmuch as they were concerned with *Hirudinea*, and in the case of the latter, with a form closely related to the species herein described. I shall undertake in this and subsequent papers to present the macroscopic and microscopic anatomy of the leech *Haemopsis marmoratis* (Say).

I have omitted from the following discussion any details of a cytological and histological nature except where imperative. This phase of the study is now under careful consideration and will appear at an early date. The writer has attempted to avoid a lengthy description of details in instances where a suitable illustration can best serve.

### METHODS

In previous papers (1943-44) the writer has outlined in detail new staining methods and modifications applicable to the leech. In general it may be repeated here that the gold chloride and silver nitrate impregnation methods provide the basis for subsequent nerve differentiation. Counterstaining with phosphotungstic acid and Masson's stain has advantages in certain instances where tissue differentiation is also desirable. All of the illustrations, except where otherwise noted, are tracings of projected sections. Reconstructions are produced from serial sections employing micro-projection equipment.

### THE NERVOUS SYSTEM OF HAEMOPSIS MARMORATIS

The gross nervous system of *Haemopsis marmoratis* is for convenience described as being composed of the following four divisions. (1) The central system, (2) the peripheral system, (3) the subepidermal system, and (4) the visceral system.

#### THE CENTRAL NERVOUS SYSTEM

The central system consists of an anterior cephalization contained in the head region, a series of segmentally arranged ganglia connected by the ventral nerve

<sup>1</sup>*Haemopsis marmoratis* (Say).

cord in the body region, and a caudalization found in the anal region. The anterior division of this system is composed of a mass of neuromeres more or less completely fused, and forming a collar about the esophagus. The dorsal mass is referred to as the brain or supra-esophageal ganglion. This portion is connected with the ventrally located sub-esophageal ganglia by the circum-esophageal connectives (Plate No. II, Fig. 1). This anterior cephalization represents six neuromeres. The criteria used in this determination conforms with that employed by Whitman (1895) and Bristol (1899) in similar studies involving the metamerism of *Clepsine* and *Nephelis*, respectively.

The anal or caudal ganglia is composed of eight neuromeres. In this region fusion and distortion has taken place but not to the same degree as in the head region just described. Here the number and arrangement of the contributing neuromeres can be easily distinguished. A reconstruction from serial sections, using the same criteria as before, unmistakably established the boundaries of each ganglion. The number and position of lateral nerves arising from this caudal mass corresponds with the capsular number and arrangement. There are eight pairs of lateral nerves, one pair emanating from each determined ganglion.

Lying between the above described terminal portions are twenty ganglia. The first eighteen are metamerically arranged, though at the extremities not equally spaced. The nineteenth and twentieth ganglia are contained within somite XXV. The first three and the last two ganglia in the ventral chain are smaller than the the ganglia of the mid-body region. The ganglia of the ventral chain are joined together by a pair of nerve trunks extending from the sub-esophageal ganglion to the anal ganglia (Plate No. I, Fig. 1). The entire ganglionic chain is contained within the ventral blood sinus.

#### *A Typical Neuromere*

The knowledge of the capsular arrangement of the nerve cell bodies in a typical ganglion is a prerequisite to the analysis of either the "brain" or "anal ganglia." The nerve cell bodies of a ganglion are arranged, in general, in six primary clusters. Two such groups occupy a median ventral position while the remaining four are dorso-laterally placed. Near the center of the ganglion the cells of the latter are found to extend to a ventral-lateral position. It is only in the brain and anal ganglia that a shift from this general arrangement is noted. The number of primary capsules, however, even at the extremities remains constant. Each primary capsule is composed of numerous secondary cell clusters.

Of equal importance in defining the limits of a neuromere are the extra capsular cell bodies. Metamerically arranged cell bodies of this type may be listed under one of two classes. First, those whose cell bodies lie within the plexiform substance and whose processes enter the capsular area. The "Gross" motor nerve cell previously described by Krawany (1905), Retzius (1892), Smallwood (1930) and others is an example of this type. The cell body of the "Gross" cell is outside the capsule and usually contained within the plexiform or fibrous portion of the ganglion. These are giant multipolar motor cells. (Illustrated Plate I, Fig. 1, Miller 1944).

In *Haemopsis*, as in *Nephelis* (Bristol) and *Clepsine* (Whitman) each body neuromere contains two "median nerve cells." The cell body of this type of "giant" cell is spindle shaped. (Plates Nos. II and III, Figs. 3 and 5). The cell bodies lie within the plexiform or fibrous portion of the ganglion in a ventral-median position. The number and arrangement of the "median nerve cell bodies" is especially valuable as an aid in determining the limits of the neuromeres contributing to the "anal ganglia."

A second class of extra-capsular nerve cells are those whose processes do not enter the capsular area. Two examples of this type of cell are found in the central system, both are "giant" bipolar cells.

The first example, Leydig's cell (Herman 1875) in addition to being outside the capsular aggregation has no connection with the plexiform or fibrous portion of the cord. It is present throughout the ganglionic chain, varying in position from between the axis of the lateral nerves of a midbody ganglion to an extra ganglionic position in the head and anal region. In the midbody region the processes of this cell leave the ganglion by way of the lateral nerves. The metameric consistency of Leydig's cell makes it a useful landmark in those areas where congestion of neuromeres has occurred. (Plate No. III, Fig. 1).

A second example of "giant" cell belonging to class two is the "colossal axial cell." (Plate No. III, Fig. 4). This type of cell will be mentioned only briefly inasmuch as it does not afford a basis for determining the limits of a neuromere. The nucleus of this cell lies about midway between the ventral ganglia within each of the two ventral connectives. The processes extend both anteriorly and posteriorly in the fibrous portion of the ventral cord. There is an experimental basis for inferring that the processes of the axial cell extend beyond the adjacent ganglia. Although my preparations clearly show the presence of inter-ganglionic processes continuing through the ganglion, a single fiber cannot be traced with accuracy over so great a distance.

I have excluded from the discussion at this time the extraganglionic neurons of the visceral and subepidermal systems. Reference to these systems will be made later in the paper.

Each body segment in *Haemopsis marmoratis* is represented in the nervous system by a ganglion. The number of segments is established as XXXIV. The distribution of the ganglia and segments is illustrated in Table No. 1. The ganglionic centers of the nervous system are simple repetitions, element for element, the "brain" and "anal ganglia" not excepted. Plate Nos. 1 and II, Figures 1, 2, 3, illustrate the numbers and arrangement of the ganglia together with their lateral nerves for the head, body and caudal regions.

### The Head Region

The head region is designated as that portion of the organism which includes the entire anterior cephalization. In *Haemopsis marmoratis* this region extends from somite I through somite VI. This region includes the first eleven annuli.

The supra-esophageal ganglion or brain rests upon the dorsal wall of the pharynx at the level of the caudal annulus of somite V. Beneath the pharynx at the level of the second annulus of somite VI lie the sub-esophageal ganglia. The esophageal connectives extend laterally and ventrally from the brain. They are directed caudad, traversing the first annulus of somite VI, and join the sub-esophageal ganglia beneath the pharynx.

In order to determine the number of neuromeres comprising this region it is essential that the capsular number and arrangement as well as the peripheral nerves emanating from it be established. Nerve trunks one and two arise together from the anterior surface of the lateral connectives. They arise as parallel nerves proceeding anteriorly some distance before separating. The nerve cell bodies comprising the capsules of the first neuromere are located on the dorsal surface of the brain. The capsules of nerve two are located on the connectives. The third and fourth pair of lateral nerves arise near the vortex of the sub-esophageal ganglia. Both pairs divide into a dorsal and ventral branch some distance anteriorly. The fifth pair of nerves arises near the center of the sub-esophageal ganglia. These nerves proceed anteriorly to the level of the connectives as a single trunk before dividing into a dorsal and ventral nerve root. The sixth and last pair of nerves emanating from the head region, arise from the apical end of the sub-esophageal ganglia. Members of this pair divide soon after leaving the body of the ganglia (Plates Nos. I, II, Fig. 1).

The number of neuromeres is thus determined to be six. Whitman (1895) established the same number and essentially the same position for the neuromeres

in *Clepsine*. Bristol (1899) found a like number and position to prevail in *Nephelis lateralis*.

### *The Body Region*

A complete body segment or somite consists of five annuli. Associated with each somite is a single ganglion located within the ventral blood sinus. In *Haemopsis marmoratis*, eighteen ganglia are contained within the body region. The limits of this region are herein defined as somites VII through XXIV.

Extending caudad from the sub-esophageal ganglia are two parallel nerve trunks. Each nerve trunk is surrounded by a connective tissue sheath. The two main trunks are contained within an envelope which is continuous throughout the central nervous system. It has been previously stated that the ventral nerve cord, as well as the segmentally arranged ganglia of the ventral chain are contained within the ventral blood sinus. The first ganglion (most cephalad) of the ventral chain is contained within the first annulus of somite VII. This is the first in a series of segmentally arranged ganglia of the body region. It is actually the seventh ganglion of the animal and although smaller in size than a mid-body ganglion it is complete in every respect. From each ganglion of the body region arise two pairs of lateral nerves. The ganglia of the ventral chain, exclusive of the caudal region, occupy the first annulus of each somite.

### *The Anal Region*

The anal region includes somites XXV through XXXIV inclusive. Somite XXV consists of two annuli, annulus 102 and 103 respectively. Somite XXVI includes annuli 104 and 105. Somite XXVII is represented by a single annulus, 106. Somites XXVIII through XXXIV are contained in the sucking disc.

Ganglion XIX of the ventral chain (the twenty-fifth of the entire series) is located within annulus 102. The XXth ganglion is contained in annulus 103. The last two mentioned ganglia are smaller than typical midbody ganglia. Each, however, contains six primary capsular aggregations of nerve cell bodies. Ganglion XX differs from the other unfused ganglia of the ventral chain in that it gives rise to a single pair of lateral nerves in deference to the usual anterior and posterior pair.

The "anal ganglia" is composed of eight neuromeres, and occupies the posterior third of annulus 103, all of annulus 104 and the anterior part of annulus 105. The components of this compressed and fused ganglia retain their fundamental characteristics and are plainly resolvable. The exact number and limits of each neuromere is established through reconstruction of the region and presented in Plate No. 11, Fig. 3.

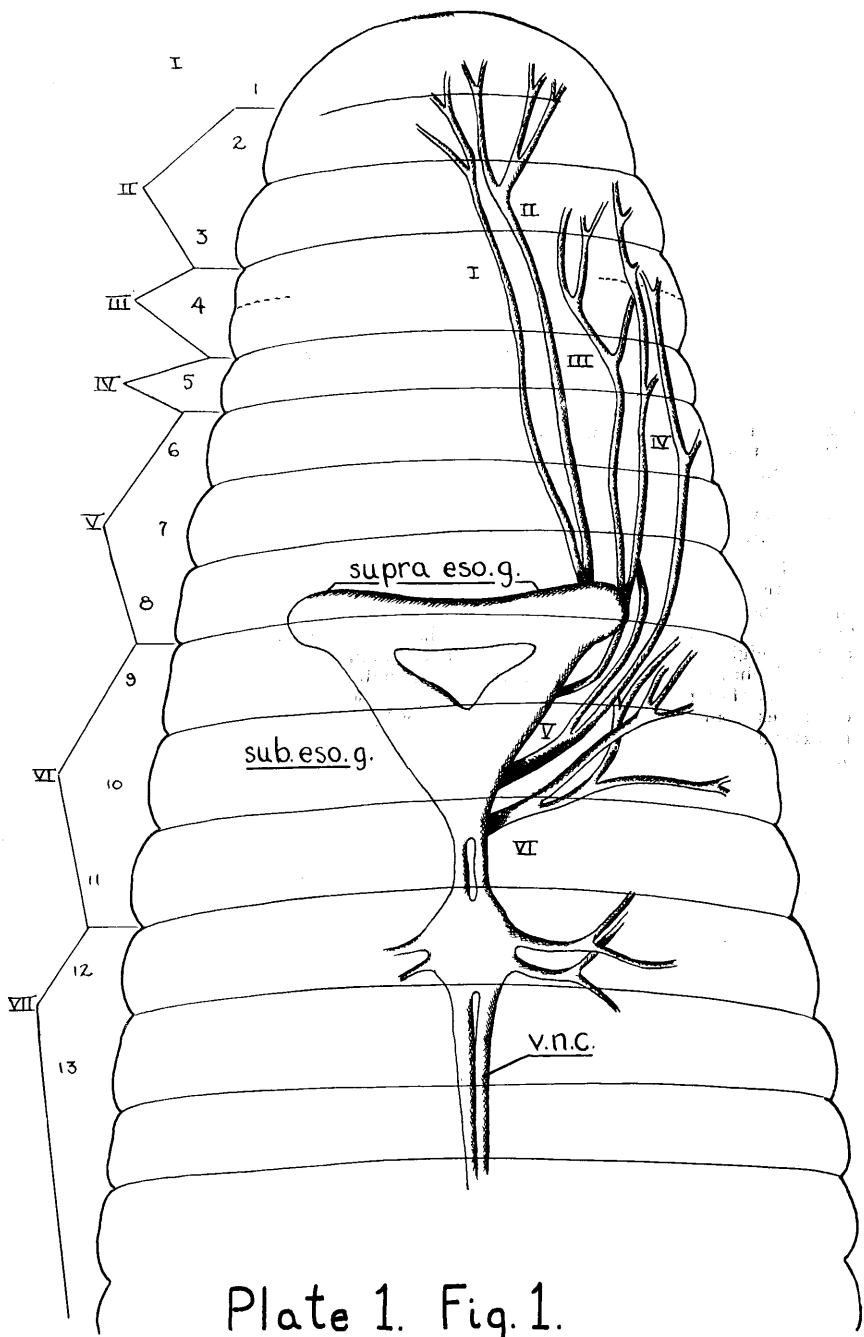
In the preceding pages I have stated that the adult *Haemopsis marmoratis* is divisible into thirty-four segments. This number is characteristic for *Hirudinea* in general as the work of many previous investigators will testify. The results of this study confirm earlier work in this respect, but I submit in deference to some that the allocation of specific segments to a particular body region cannot be made by generalizing from a study of a species or two.

### EXPLANATION OF PLATE I

FIG. 1. This is a dorsal view of the anterior portion of *Haemopsis* illustrating the metameric position of the central and peripheral nervous systems within the first seven somites. The somites are indicated by Roman numerals and the annuli are numbered in Arabic figures. The paired peripheral nerves are illustrated on the right and are numbered by Roman numerals. (The nerves on the left side are omitted for clarity).

### ABBREVIATIONS

sub. eso. g. .... subesophageal ganglia      supra. eso. g. .... supraesophageal ganglia  
v.n.c. .... ventral nerve cord



## EXPLANATION OF PLATE II

FIG. 1. This is a reconstruction of the nervous system of the head region as viewed from the lateral aspect. The central, peripheral and visceral systems are included in a single drawing to illustrate their relationship as well as their metameric position. The origin and general distribution of the peripheral nerves emanating from the right side of the collar and subesophageal ganglia are illustrated and numbered. The first ganglion of the ventral chain is included in this illustration and occupies the first annulus (No. 12) of somite VII. The visceral nervous system, as viewed from the right side, shows a ganglionic mass, circumesophageal trunks and anterior-posterior fibers.

FIG. 2. This is a lateral view of the posterior portion of *Haemopsis* as reconstructed from serial longitudinal sections. The anatomical relation and metameric position of the ganglia and peripheral nerves in the caudal region are illustrated. The ganglia of the ventral chain are numbered in Roman numerals from I to XX inclusive. The six ganglia contained in the head region and the eight ganglia comprising the "anal ganglia" together with the twenty ganglia of the ventral chain constitute the thirty-four ganglia of the leech. (Ganglia XX of the ventral chain is therefore the twenty-sixth ganglion of the leech.) A single pair of lateral nerves emanates from ganglion XX. Eight pairs of lateral nerves, one from each contributing ganglion, extend from the "anal ganglia." The five anterior pairs are directed caudad, the posterior three pairs unite in forming a large caudal nerve trunk.

### ABBREVIATIONS

anal. g.....	anal ganglion	sub. eso. g.....	subesophageal ganglia
ant. n.....	anterior nerve	v. b. s.....	ventral blood sinus
d. l. cap.....	dorso-lateral capsule	vis. f.....	visceral fibers
l. n. s.....	lateral nerves	vis. g.....	visceral ganglion
med. n. c.....	median nerve cell body	vis. t.....	visceral trunks
post. n.....	posterior nerve		

Fig. 1.

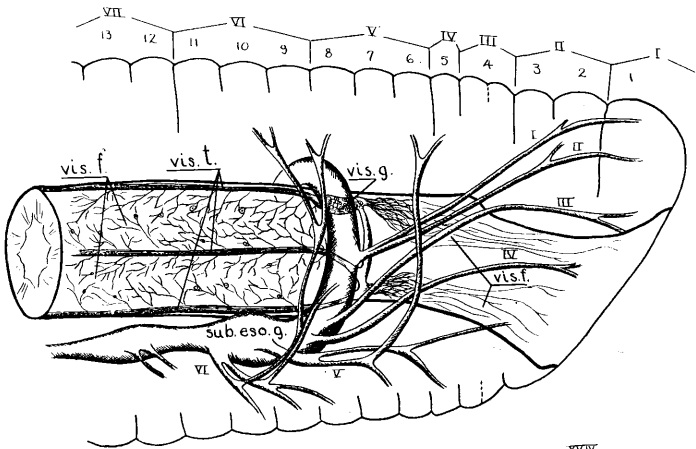


Fig. 2.

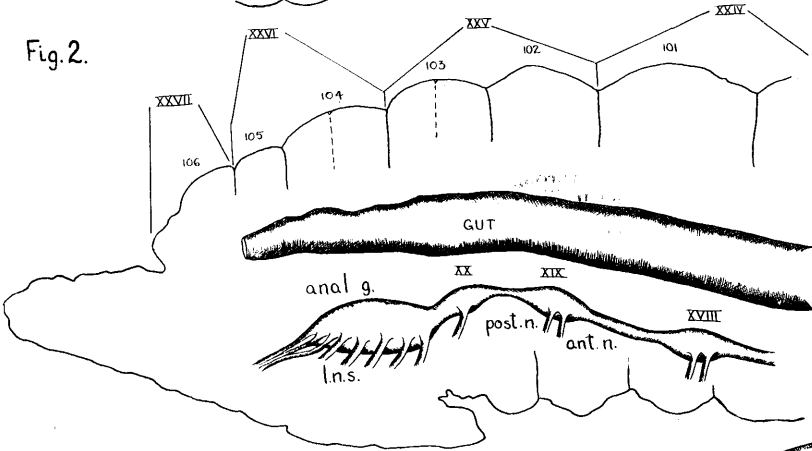


Fig. 3.

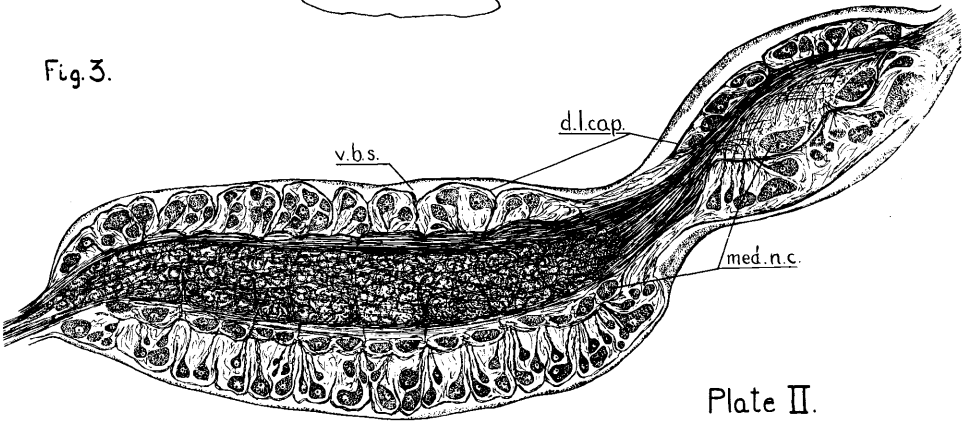


Plate II.

### EXPLANATION OF PLATE III

*Note.*—The drawings in Plate III are traced from projected sections. Each with a magnification of 50 diameters.

FIG. 1. This is a horizontal longitudinal section through the dorsal hemisphere of a mid-body ganglion. A portion of each of the dorsal paired capsular areas (d. p. cap.) is illustrated. Many fiber tracts, nerve cell bodies and processes have been omitted in order to illustrate the general pattern. Leydig's cell (L. c.) is shown in the extra-capsular area between the anterior and posterior lateral nerves.

FIG. 2. This is a cross-section through a mid-body ganglion at the level of the posterior nerve.

FIG. 3. This is a cross-section through a mid-body ganglion just anterior to the anterior nerve.

FIG. 4. This is a cross-section through the ventral nerve cord about mid-way between ganglia. This section was selected to illustrate the cell body of a colossal axial cell. (c. a. c.)

FIG. 5. This is a cross-section of a mid-body ganglion at the level of the cell body of a median nerve cell. (med. n. c.)

### ABBREVIATIONS

ant.....anterior  
ant. l. n.....anterior lateral nerve  
a. p. t.....anterior-posterior fiber tracts  
c. a. c.....colossal axial cell  
d. l. f.....dorsal longitudinal fiber tracts  
d. p. cap.....dorsal primary capsule  
ex. cap.....external capsule  
int. cap.....internal capsule  
L. c.....Leydig's cell

l. f.....longitudinal fibers  
l. n.....lateral nerve  
med. v. cap.....median ventral capsule  
med. n. c.....median nerve cell  
plex. sub.....plexiform substance  
post.....posterior  
post. l. n.....posterior lateral nerve  
v. b. s.....ventral blood sinus  
v. l. b.....ventral longitudinal fibers



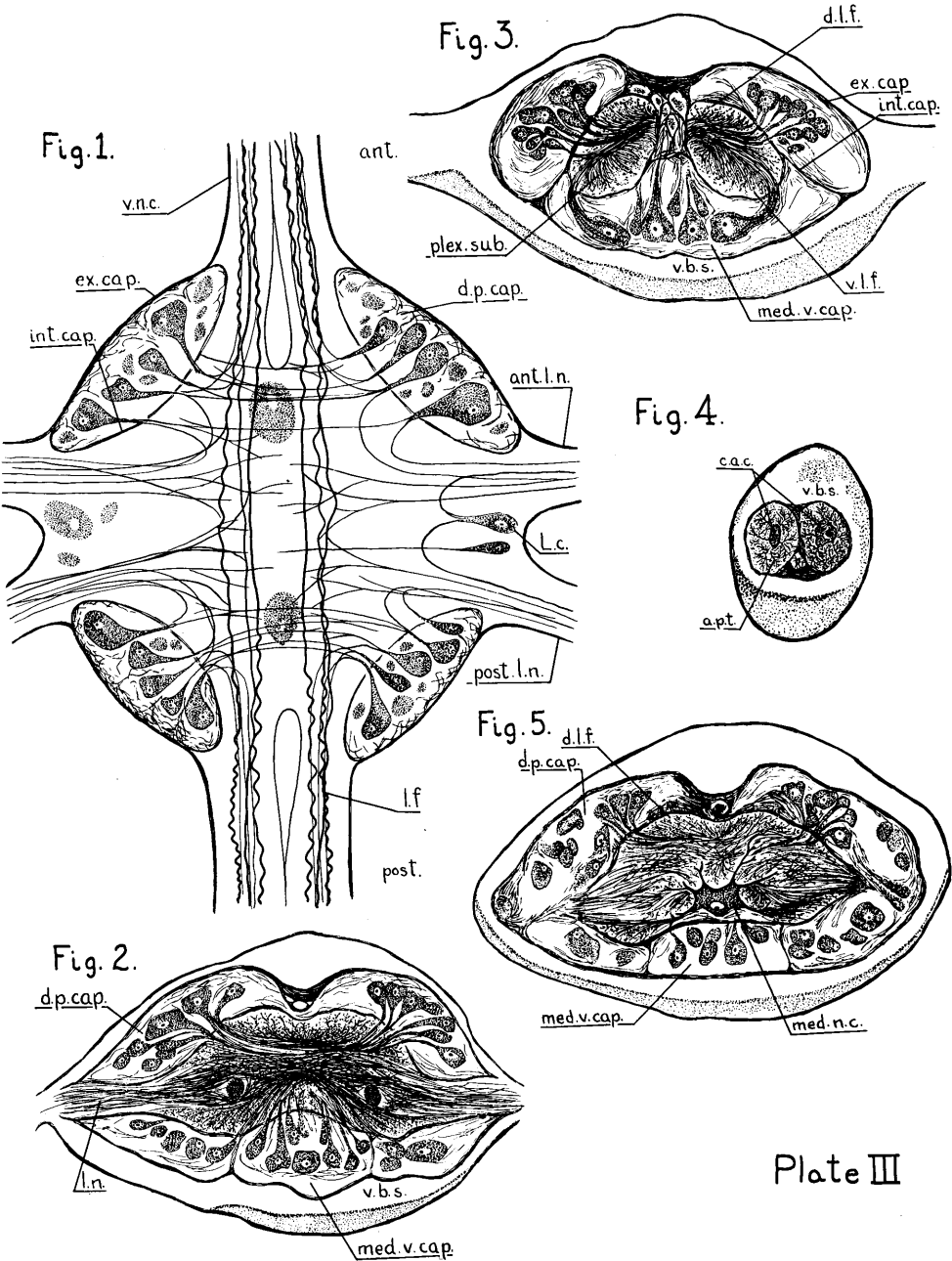


Plate III

I have defined three regional divisions for the leech under consideration, namely, the head region, the body region and the anal region. In each division the number of neuromeres correspond to the number of segments, as follows, the head region six; the body region eighteen; and the anal region ten. I classify however, the first two ganglia (XXV and XXVI) of the anal region as ganglia of the ventral chain exclusive of the "anal ganglia." Thirty-four ganglia are thus determined and distributed, one for each body segment.

TABLE I

Head Region consists of: Somites I to VI incl.	Head Region contains: Ganglia I to VI incl.
Body Region consists of: Somites VII to XXIV incl.	Body Region contains: Ganglia VII to XXIV incl.
Anal Region consists of: Somite XXV Somite XXVI Somites XXVII to XXXIV	Anal Region contains: Ganglia XXV and XXVI Ganglia XXVII to XXXIV No ganglia

THE PERIPHERAL NERVOUS SYSTEM

In this system are included the paired lateral nerves and their branches emanating from the ganglionic masses of the central nervous system. From each ganglion of the body region there arises two pairs of lateral nerves. They emerge from the lateral border of the ganglia extending in a horizontal plane at right-angles to the long axis of the body. The anterior pair emerges near the center of the ganglion, the second pair just posteriorly to the first. Each lateral nerve separates a short distance from the ganglion into a dorsal and ventral branch. The divisions and subdivisions of these lateral nerves innervate a portion of the preceding segment as well as the segment in which they arise.

The nerves of the anterior pair are not single nerves as careful study will disclose. Each one is formed by the fusion of a dorsal and ventral root. The fibers of the dorsal and ventral root combine to form a single nerve trunk at the point where the lateral (anterior) nerve leaves the body of the ganglion. There is no evidence that the posterior pair arises in the manner just described for the anterior pair. It might be of interest to state that in certain leeches, *Clepsine* for example, there are three pairs of lateral nerves per segment. It has been suggested by some writers that in those leeches possessing but two pairs of lateral nerves per segment, that the anterior pair represents a fusion of the first two in those forms having three pairs per segment.

Exceptions to the above described pattern in the midbody region are found in the head and anal regions. In the head region a single pair of lateral nerves emanates from each of the first five established ganglia. The branches of these five extend to the anterior margin of the prostomium and oral sucker. From the sixth and last ganglion of the head region emerge two pairs of lateral nerves. These innervate the sixth segment in a pattern comparable to that described for a midbody segment.

In the anal region ganglion XIX gives rise to two pairs of lateral nerves and as such does not differ anatomically, except in size, from a midbody ganglion. Ganglion XX is the last and also the smallest in the ventral chain. Emerging from the posterior third of this ganglion is a single pair of lateral nerves which is directed caudad. From their position and structural composition they should be considered as homologous to the posterior (second) pair of lateral nerves of a typical ganglion. The branches of this nerve extend into somite XXVI.

The anal ganglia, consisting of eight neuromeres, give rise to eight pairs of lateral nerves. The first pair innervates somite XXVII, the remaining seven pairs innervate the sucker. The last three pairs emerge from the posterior

boundary of the anal ganglia and proceed posteriorly as a group. (See Plate No. II, Figs. 2 and 3).

#### THE SUBEPIDERMAL NERVOUS SYSTEM

The presence in annelids of a nerve net outside the central nervous system has been previously reported by a number of investigators. Among them, Bristol (1899) refers to the "intermuscular nerve ring," Langdon (1905) and Ogawa (1934-39) include in this system the nervous components of the baseepiment. Hess (1925) in referring to the subepidermal nerve plexus, includes the segmental nerve rings and their peripheral components. In Hess's paper (1925) on *Lumbricus* there is presented the functional as well as anatomical relations of this system to the central nervous system. A preliminary description of the subepidermal system of *Haemopsis* is given in a previous paper by the author. Miller (1933). Improvements in invertebrate neurological technique, Miller (1944) have made possible the following supplementary statements relative to this phase of the nervous system in *H. marmoratis*.

The intermuscular nerve rings are segmentally located in the second and fifth annulus of each complete somite. Each nerve ring has, as previously reported, a dorso-lateral and ventro-lateral concentration of nerve cell bodies. Lesser aggregations of cell bodies are found more medially than reported earlier. All of the observed cell bodies of this ring are located within the median longitudinal muscle later. The processes of these cells, combine with the processes of the more peripherally located nerve cells on the baseepiment forming a network beneath the circular muscle layer. This network is connected with the central nervous system through peripheral fibers of the paired lateral nerves.

The segmentally arranged intermuscular nerve rings are joined with each other by anterior-posterior connectives. These connectives have been described as single neurons more or less evenly spaced over the dorsal, lateral and ventral surfaces. Further that the cell bodies of these connectives are located some distance from the nerve rings. (Bristol (1899) for *Nepheleis lateralis*). Experimental as well as anatomical evidence verifies the existence of such connectives in *Haemopsis marmoratis*. In preparations available to me only dorso-lateral and ventro-lateral connectives are resolvable, and they appear to consist of numerous fibers. The location of the cell bodies of these connectives has not as yet been determined. These connective fibers join with those of the nerve ring in the regions of concentration of cell bodies.

The function of the peripheral system is of utmost importance in understanding certain phases of annelid behavior. I have discussed this aspect at some length in previous papers (Miller 1933-36). An accurate knowledge and an adequate understanding of the nervous system is a necessary prerequisite to the analysis of the behavior of any animal.

#### THE VISCERAL NERVOUS SYSTEM

This division of the nervous system is referred to by most investigators as the sympathetic system. As far as I am able to determine this portion of the nervous system is associated entirely with the visceral organs, and is not metamerically arranged. The only demonstrable connection with the central system is in the region of the esophageal connectives.

The ganglionic masses of the visceral system are confined to annulus eight. They lie medially in relation to the esophageal connectives and are partly obscured by them. They consist of ganglia located on the dorso-lateral surface of the pharynx and joined by a wide circumesophageal band of connectives. Numerous bundles of nerve fibers extend from this visceral nerve center.

From the ganglionic masses there extends anteriorly numerous bundles of fibers into the buccal cavity. Posteriorly similar bundles extend laterally over the surface of the alimentary tract. In addition to the lateral bundles just mentioned there is a dorsal and a ventral bundle extending from the connectives, the fibers of which form a plexus with the branches of the lateral bundles. The muscular surface of the alimentary tract is in this manner covered with an intricate network of fibers. These fibers are however, of two types regarding their origin. Many of them are continuations from the dorsal, ventral and lateral bundles. Others are the extensions of multipolar nerve cells, the cell bodies of which lie within the muscular wall itself. This system is continuous over the entire viscera. (Plate No. II, Fig. 1).

The histology of the entire nervous system of *Haemopsis marmoratis* will be presented by the author in the very near future.

#### SUMMARY

1. This study is concerned with a single species of leech, *Haemopsis marmoratis*, (Say).
2. Silver nitrate and gold chloride impregnations provide the basis for nerve differentiation.
3. The illustrations are tracings of projected sections or reconstructions from serial sections.
4. The gross nervous system is composed of four divisions; namely, (1) central, (2) peripheral, (3) subepidermal, and (4) visceral.
5. The leech is divided into three regions; namely, (1) head, (2) body and (3) anal.
6. The central nervous system consists of an anterior cephalization contained in the head region, a series of segmentally arranged ganglia connected by the ventral nerve cord in the body region, and a caudalization found in the anal region.
7. The anterior cephalization represents six neuromeres, and is contained within somites V and VI.
8. Excluding the subesophageal and anal ganglia there are twenty ganglia in the ventral chain. The first eighteen of which are within the limits established for the body region, the remaining two ganglia are in the anal region.
9. The anal or caudal ganglia is composed of eight neuromeres, and is contained within somites XXV and XXVI.
10. The adult body of *H. marmoratis* is divisible into thirty-four segments. Thirty-four ganglia are resolvable and distributed as just indicated.
11. The ganglia of the ventral chain are joined by a pair of nerve trunks extending from the subesophageal ganglia to the anal ganglia. This portion of the central system is contained within the ventral blood sinus.
12. In each ganglion the nerve cell bodies are contained, for the most part, within six primary capsules, two are median ventral, four are dorso-lateral.
13. Extra-capsular nerve cell bodies are found in the central nervous system, within the ventral nerve cord, within the plexiform substance of the ganglia, and within the ganglia but outside the capsule.
14. Six pairs of lateral nerves arise from the anterior cephalization consisting of the brain, circumesophageal connectives and subesophageal ganglia.
15. Extending laterally and in a horizontal plane are two pairs of lateral nerves emanating from each body region ganglion.
16. The anterior pair of nerves is formed by the union of a dorsal and ventral root.
17. From the posterior third of ganglion XX there emerges a single pair of lateral nerves.
18. Emanating from the anal ganglia are eight pairs of lateral nerves. The three posterior pairs emerge as a group and are directed caudad.

19. Intermuscular nerve rings are segmentally located in the second and fifth annulus of each complete somite. With each nerve ring is associated a dorso-lateral and ventro-lateral aggregation of nerve cell bodies.
20. The peripheral nerve net is situated beneath the circular muscle layer, and is connected with the central system through peripheral fibers of the paired lateral nerves.
21. The visceral (sympathetic) division of the nervous system is associated entirely with the visceral organs. There is no indication of segmentation and its only connection with the central system is in the esophageal region.
22. The ganglionic masses of the visceral system are confined to annulus eight. Bundles of fibers emanating from the visceral ganglia extend anteriorly into the buccal cavity and posteriorly over the surface of the viscera.
23. Posterior visceral fibers, supplemented by processes from nerve cells in the viscera form a plexus over the surface of the organs.

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#### New Crops for the New World

This book is of paramount importance to those who are interested in tropical agriculture and particularly in the new phases that have developed in Latin America. Dr. Wilson Popenoe has contributed two of the chapters, "The undeveloped field of tropical fruits" and "Cinchona, the fever tree." From his years of experience as plant explorer, research director for the United Fruit Company and now Director de la Escuela Agricola Panamericana, Popenoe is known far beyond his special field of interest. Edgar Anderson, Albert O. Rhoad, Miriam L. Bomhard, Walter N. Bangham, E. C. Higbee, C. P. Clausen, Arthur Bevan, George E. Adames, Atherton Lee, A. T. Erwin, B. Y. Morrison, P. Honig, and V. C. Dunlap complete the list of contributors to make a book that contains too much carefully worked over data entertainingly presented to fit into a brief review. At no time before have so many biologically trained persons all directed their effort toward the development of western hemisphere crops. The reader can gain an understanding of what the world may expect from teamed effort.—A. E. Waller.

**New Crops for the New World.** Edited by Charles Morrow Wilson. The Macmillan Company, New York, 1945, pp. 295. \$3.50.